3.3.2 Test Set-Up

The low frequency attenuated pulse was fed to SMIN exactly as in the cw case, and test set-up and procedure are precisely the same (Figures 15 and 18) with replacement of PSG 1000 by Systron Donner 101 Pulse generator and 4700 pF capacitor. However, determination of TOI and measurement of pulse generator output correlated to TOI differs from the cw case.

3.3.3 TOI Determination

In the cw case, rfi was evidenced by a 400 Hz tone in radios' audio output due to a beat frequency effect between broadcast and interference frequency. With a 400 Hz pulse repetition rate, rfi tone appeared not only at 400 Hz, but at all harmonics of 400 Hz within radio pass band. Nevertheless, the 400 Hz fundamental was highest in level and was used to establish TOI. Figure 28a shows baseline radio audio output (no conducted rfi) while Figure 28b shows rfi effects. In both figures, highest peak represents audio output due to reception of 1.1 MHz simulated broadcast signal with 30% 1 kHz AM. In Figure 28b, closest peaks to 1 kHz broadcast signal are 800 Hz (just left of broadcast response) and 1200 Hz (just right of broadcast response) harmonics of 400 Hz repetition rate, which is second highest peak overall (6 dB down from broadcast signal per TOI criteria).

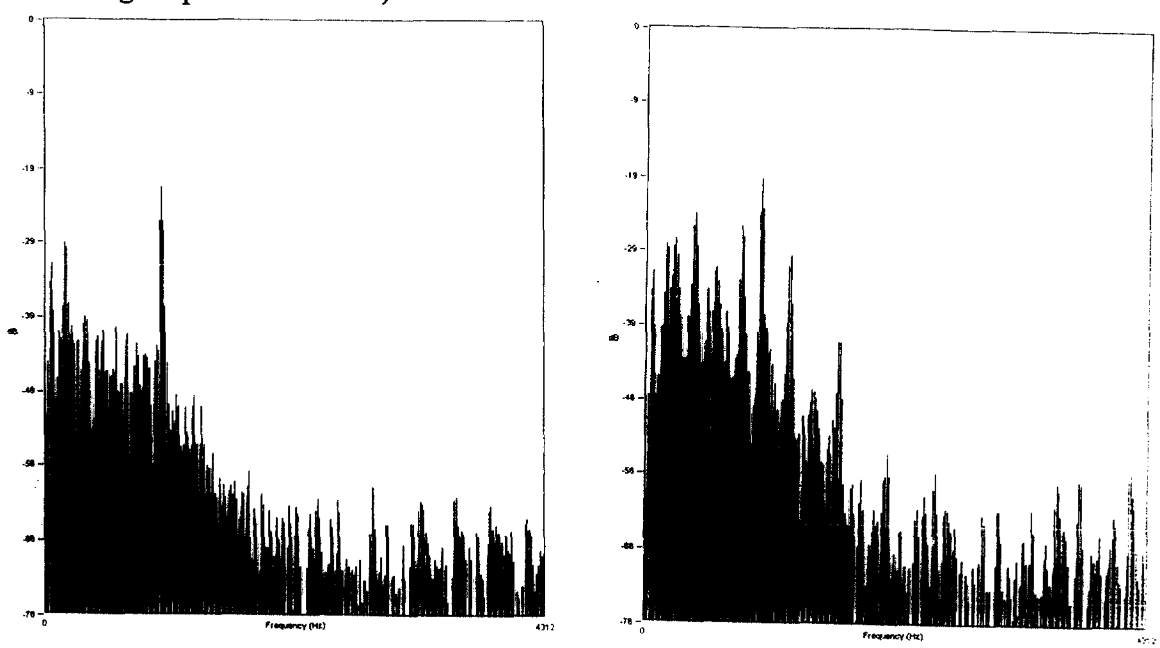

Figure 28: *TOI determination with broadband rfi source*

In the cw case, when TOI had been established via audio measurement, it sufficed merely to record Farnell PSG1000 output reading. This is not possible in a meaningful manner with a pulse generator. Pulse generator output was disconnected from SMIN and fed to a spectrum analyzer. Spectrum analyzer reading, using a 9 kHz measurement bandwidth, at radio tuned frequency was recorded as pulse generator output. Necessarily, the reading is so many dBμV in a 9 kHz bandwidth. Especially when measuring dm TOI, which in each case exceeded pulse generator max output, external spectrum analyzer attenuation was required to provide linear response.

3.3.4 Synopsis

Any dm limit relaxation appropriate for cw rfi sources is valid as well for broadband sources.

4.0 RAMIFICATIONS OF CE CONTROL BY MODES: DECREASED COST OF RF FILTER IMPLEMENTATION FOR OFF-LINE CONVERTER

As stated in introductory paragraphs, present day CE control has proved *sufficient* to protect AM band receivers. The issue raised in this report is whether present CE control is *totally necessary*. Results presented in Section III argue for relaxation of dm CE limits, while maintaining cm control at levels presently levied by the US FCC (CISPR limits appear too lax). However, the value of such "tinkering" with present limits and methods of control has yet to be demonstrated. Admittedly, new mode-specific CE control complicates compliance testing; a payoff in less complex (less costly) filter design must more than offset this complication.

It is more complicated and expensive to filter dm emissions than cm for an off-line supply for the following reasons. Capacitors installed phase-to-ground must meet stringent safety related requirements. When these requirements are combined with the value of capacitors necessary to filter dm emissions, price is high. Inductors inserted differentially must handle peak line current without saturation. This effectively limits inductance values to 50 μH or less for loads drawing more than two Amps. Contrast these design constraints with those imposed on the cm section. Safety requirements on line-to-ground (Y-) capacitors are similar to X-capacitors, but with an added limit on line-frequency leakage current; this effectively limits Y-capacitor values to 3000 - 10,000 pF range. These capacitors are relatively inexpensive. Common mode inductance is not limited by saturation concerns; a well-constructed cm choke controls leakage inductance to a level just below that causing saturation (Nave, 1991). *Therefore, if for cost reduction purposes, one were to pick a single CE mode for limit relaxation, the mode selected would be differential. Fortunately, in preceding sections, it is precisely that mode's limit which was found suitable for relaxation.*

For instance, the X-capacitor meeting safety requirements and suitable for use on a 1 kWatt SMPS costs about $2.00 (all prices quoted in this paragraph based on lot buys of a few hundred). A similar X-capacitor used on a 200 Watt supply costs $0.50. The difference in power is 7 dB. Clearly, a 20 dB relaxation in the dm CE limit will significantly reduce the size and therefore the cost of the X-capacitor. Similarly, a dm choke designed for a 1 kWatt SMPS costs $10.00 in vs. $3.00 in a 200 Watt supply.[12] An off-the-shelf replacement 250 Watt PC SMPS retails around $50.00. A PC manufacturer buying thousands of these a month will get them at less than half this cost. It is not hard to see that a specification limit change that allows smaller X-caps and dm chokes saving even a few pennies per SMPS is a major cost-savings to the industry. An example of how tight profit margins drive EMI designs is as follows. A keyless remote entry was designed for the automotive industry. Target price was about $50.00. Receive unit failed radiated susceptibility. A viable fix was 1 μF caps bypassing microprocessor inputs/outputs. This was suggested because 0.1 μF caps in same configuration reduced but did not eliminate the susceptibility. This fix was not implemented (or even tried) because the manufacturer bought 0.1

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[12] An off-the-shelf 200 W or 250 W switcher such as used in a desktop PC doesn't even use dm chokes; they are uneconomical. However, such SMPS do not meet FCC CE requirements when operated at maximum capacity. Power supply manufacturers are relying on PC manufacturer derating to allow their supplies to "loaf," running well below rated output.

μF caps by the million, vs. much lower quantities for 1 μF caps. The penny difference per cap made the suggested fix impractical.

4.1 Suggestion For Proving The Efficacy/Utility of Relaxing The Differential Mode Emission Limit

A full compliance filter for an OEM 200/250 Watt off-line power converter would be developed. This switched mode power supply, hereinafter simply designated SMPS, would either be a new development, or an off-the-shelf unit with rf filter section disabled. The SMPS thus would not meet CISPR 22B CE limits or FCC Class B. A full compliance filter would be compared to a filter which meets present limits for cm CE, but is allowed a 20 dB dm relaxation. Radio response each SMPS configuration would be measured, to ensure that relaxed emissions cause no more rfi than traditional limit.

4.1.1 TEST DESCRIPTION

Test Set-Up

Victim radio(s) and SMPS would be powered from same LISN. Radio installation and instrumentation is identical to that shown in Figure 15, except that shielded enclosure may now be a screen room, since resistive load bank for SMPS is large and needs air circulation. Set-up shown in Figure 29 has SMPS and load bank outside enclosure, which is necessary if small enclosure is used. Baseline radio audio response to simulated broadcast signal with no rfi would be measured and recorded.

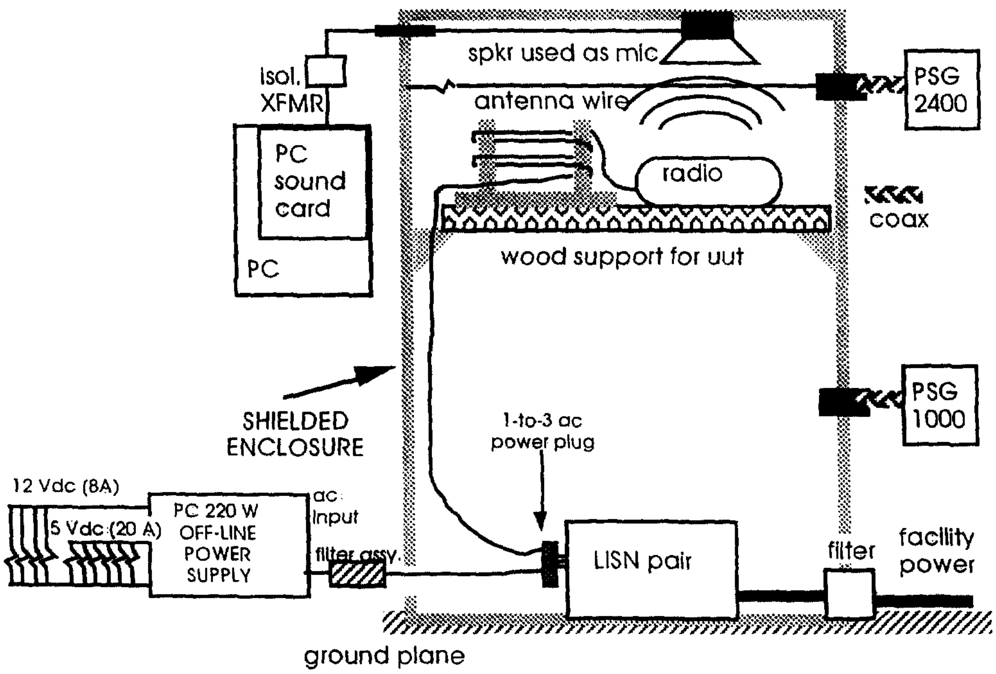

Figure 29: *Set-up for measuring effect of SMPS cm/dm CE on radio receiver victim*

Test Procedure

Various filter configurations would be tested. Radio response to baseline (unfiltered) SMPS emissions would be measured. With radio tuned to SMPS switching frequency harmonics, full disruption is expected. Next, a full-compliance filter would be designed, and its full protection of radio reception verified.

Various dm filter changes would be evaluated (cm stage untouched from full-compliance configuration). Radio response to a cm stage only with no dm stage would be measured. Next, a dm stage that would just meet a limit 20 dB relaxed from traditional limit would be implemented. Radio response to this level of rfi would be measured, recorded, and compared to that resulting from full-compliance filter.

Test Conclusions

Expected test results would be that filter configuration would be less complex, require less PCB real estate, and cause no more radio interference than full-compliance filter configuration.

5. Conclusion/Recommendation

The response of over thirty radio receivers to power-line conducted noise was evaluated as to their susceptibility to common and differential mode noise.

Study results demonstrated that radios are much more susceptible to common mode noise than to differential mode noise. Statistically significant differences between these responses strongly suggest the efficacy of procedures and limits which separately control cm and dm conducted emissions.

Author's recommendation is the adoption of new standards which reflect real radio rfi susceptibility. Such regulatory action will decrease the cost of EMC compliance, with benefits resulting to the entire electronics marketplace.

5.1 A FURTHER EXTRAPOLATION

Some radios have a lower dm threshold of interference than others. The dm TOI of Radio #22 was fairly low, 60 dBμV, but addition of a 0.047 μF X-capacitor raised its dm TOI to 80 dBμV. Conclusion here is that a nominal impact dm immunity requirement (placed on radios) would serve to relax emission requirements on culprit emitters. Consider progression of filter configurations discussed in this report:

full compliance on emitters (multiple stage filter), none on victims

relaxed dm requirements on emitters, none on victims

(effectively) no dm limit on emitters, nominal immunity requirement on victims

The trade-off here is a part costing a few pennies in a product typically costing under $20.00 vs. parts (large X-cap, dm choke) costing a significant fraction of a dollar in a product (power supply probably also costing $20.00, but part of a PC retailing at about $1000.

5.1 ACKNOWLEDGEMENTS

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Wayne Kerr, Inc. provided long term loan of an rf spectrum analyzer and two synthesized rf signal sources, the PSG 1000 and PSG 2400. Because the test technique relied on the simulated broadcast signal and rfi signal to maintain a constant 400 Hz separation at frequencies in the AM band, the precision and long term stability of these generators were invaluable.

Mr. Mark Nave of EMC Services designed the selectable mode rejection network (SMIN) per the author's specification and at his request. The SMIN was at the very heart of the test method. Mr. Nave also offered many helpful suggestions over the course of the study.

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Mr. Duane Driver assisted with test fixture design/build and in running radio TOI tests.

Any errors of omission or commission are solely the author's.

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